

SECTION 5.0

EMISSIONS FROM MAJOR USES OF BUTADIENE

Emissions from industrial processes using butadiene as a raw material are discussed in this section. Butadiene has six primary commercial uses, as illustrated in the chemical use tree in Figure 3-1. These uses are the production of styrene-butadiene (SB) copolymer, polybutadiene, adiponitrile, neoprene, acrylonitrile-butadiene-styrene (ABS) copolymer, and nitrile elastomer.

This section includes a subsection for each major use. Each subsection provides a general discussion of the production process, estimates of the associated butadiene emissions, and a description of any existing emissions control practices. These discussions are primarily based on summary memoranda of industry responses to EPA Section 114 questionnaires, National Institute for Occupational Safety and Health (NIOSH) survey reports, and various other reports as referenced, and represent information gathered prior to 1986. The level of detail varies according to the availability of information. In view of these limitations, the reader is advised to contact individual facilities or review State permit files for more complete and accurate information.

As with butadiene production sources, emission factor ranges in units of pounds (kilograms) butadiene emitted per ton (megagram) produced are provided for process vents and secondary sources, based on annual emissions estimates of tons/yr (Mg/yr). The same procedure described in Section 4.0 for calculating facility emission factors was followed to establish these ranges. Assumptions about production are provided in each subsection.

Equipment leak emissions are presented as annual emissions and were derived using the procedure in Appendix D and the CMA emission factors presented in Section 4.0. Although developed for butadiene producers, these emission factors were assumed to better represent practices of the user industries because all involve butadiene handling. Three alternative methods would be to (1) collect screening data and use correlation equations established in the CMA work, (2) apply SOCMCI emission factors, weighted for the percent butadiene in the stream, or (3) apply other alternatives identified in the EPA document *1995 Protocols for Equipment Leak Emission Estimates*.¹ The equipment leak emission estimates generally represent some level of control because the average emission rate is based on practices at butadiene producers.

The emission factors and annual emission values should be used only as estimates because facilities did not always provide complete information, and source characteristics cannot be assumed to be the same from location to location. The number of facilities included in establishing the range is indicated in parentheses; the individual values are reported in Appendix C.

Company identification and corresponding facility locations for the various production process are also given in each subsection. The production capacities supplied are, in most cases, taken from more recent (1992-1993) references.

5.1 STYRENE-BUTADIENE COPOLYMER PRODUCTION

Styrene-butadiene copolymers are composed of the monomer units butadiene and styrene. Depending upon the feed composition and extent of drying in the process, SB copolymers can be a solid or an emulsion.

Copolymers of styrene and butadiene that contain over 45 percent butadiene have rubber-like properties. The copolymers become more plastic-like when the styrene content is increased to above 45 percent.²⁷ Copolymers with more than 45 percent butadiene are sometimes referred to as styrene-butadiene rubber (SBR); products with more styrene may be

referred to as SB latex. No distinction is made in the following discussion because emissions data are not differentiated. The term elastomer will be used in a generic sense, meaning solid copolymer.

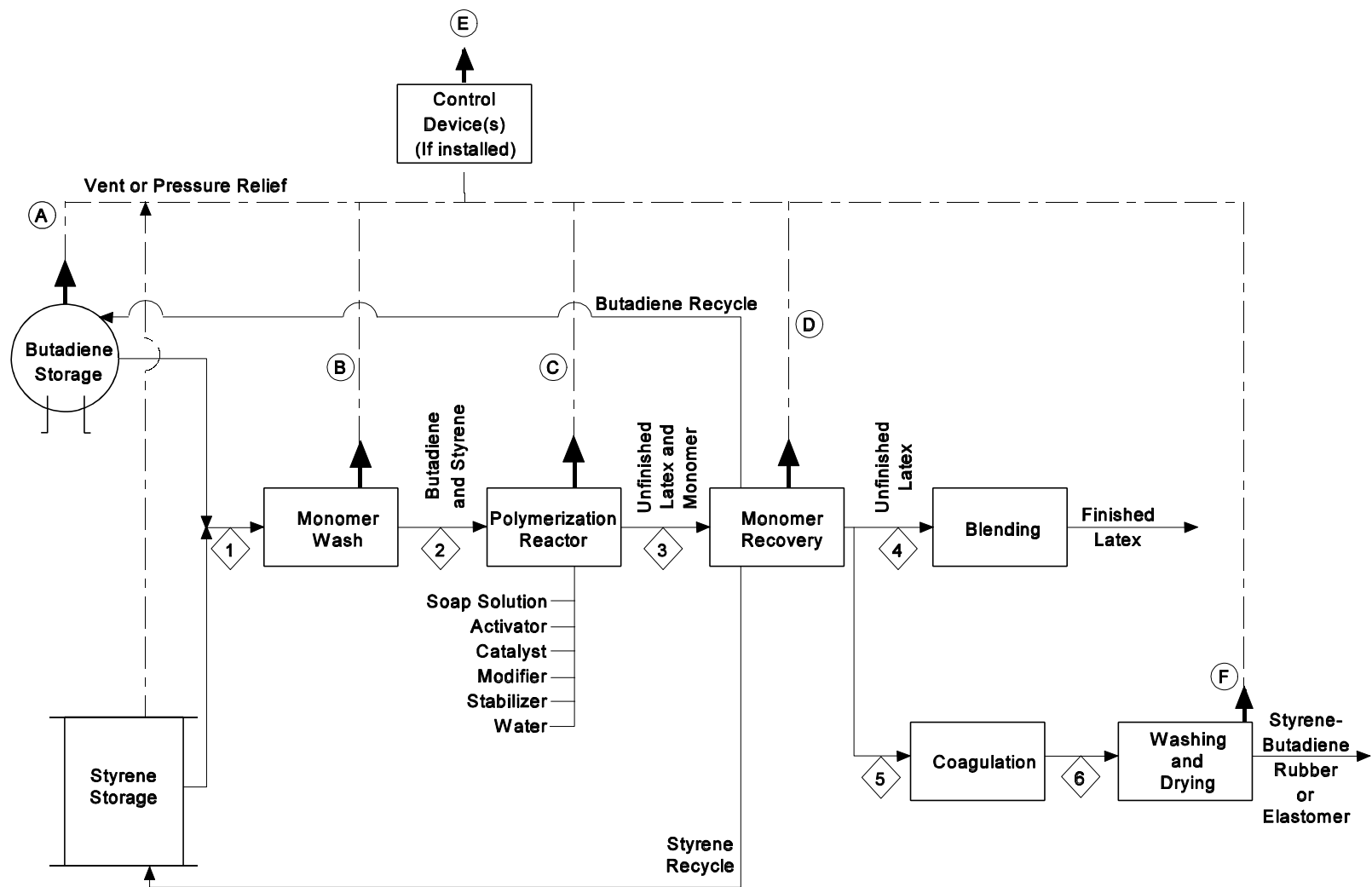
Styrene-butadiene latex is an elastomer emulsion. Styrene-butadiene rubber is also used as an emulsion. The emulsion process is the same process used for elastomers, except that it lacks the emulsion breaking (coagulation) and drying steps. The term latex is used here when referring to both SB and SBR emulsion.

Styrene-butadiene copolymers account for 40 percent of national butadiene consumption.⁸ The majority of SB elastomer produced is used by the tire industry. Latex has a wider variety of uses in industries such as textiles, paper, and adhesives manufacturing.

5.1.1 Process Description

Elastomer is manufactured by two processes: (1) the emulsion process, where monomer is dispersed in water, and (2) the solution process, where monomer is dissolved in a solvent. The emulsion process is more commonly used. Latex is similarly produced but is removed prior to the final processing that generates the solid copolymer.

A generalized block flow diagram of an elastomer and latex production process is shown in Figure 5-1.²⁷ Stored butadiene and styrene monomers are first washed to remove any inhibitors of the polymerization reaction (Step 1). The scrubbed monomers are then fed into polymerization reactors (Step 2) along with the ingredients listed in Table 5-1.²⁸ After the polymerization reaction has progressed to the desired extent, a polymer emulsion (latex) is removed from the reactors along with unreacted monomer (Step 3). Both styrene and butadiene are separated from the latex and recycled to the monomer feed tanks.



Source: Reference 27

Figure 5-1. Process Diagram for Production of SB Copolymer

940047-FLW-ja-RTP

TABLE 5-1. TYPICAL RECIPE FOR EMULSION SBR

Components	Weight Percent	Function
Butadiene	25.0	Monomer
Styrene	10.0	Monomer
d-Isopropyl Benzene Hydroperoxide	<.1	Catalyst
Ferrous Sulfate	<.1	Activator
Tert-Dodecyl Mercaptan	.1	Modifier
Potassium Pyrophosphate	.1	Buffer
Rosin Acid Soap	1.4	Emulsifier
Water	63.0	

Source: Reference 28.

The unfinished latex may take one of two routes after monomer is removed. One route is for the latex to be blended into a homogenous emulsion (Step 4) and stored as finished latex. The other route involves a coagulation operation where the emulsion is broken (Step 5). This step is followed by washing and drying the polymer into a solid form (Step 6).

Table 5-2 lists the known production facilities, grouped by copolymer type.²⁹ Because three different latexes may be produced--SBR, SB, and styrene-butadiene-vinylpyridine (SBV)--the table indicates which copolymer(s) each facility manufactures.

5.1.2 Emissions

The emission sources at an SB copolymer facility are typical of those common to chemical production facilities: process vent discharges; equipment leaks; wastewater, liquid waste, or solid waste discharges (secondary emissions); storage-related releases; and accidental or emergency releases. Available emissions data are limited to emissions from process vents, equipment leaks, and secondary emissions, and are shown in Tables C-5 through C-8

TABLE 5-2. STYRENE-BUTADIENE ELASTOMER AND LATEX
PRODUCTION FACILITIES

Company	Location	Capacity in 1993 tons/yr (Mg/yr)	
<u>Elastomer</u>			
Ameripol Synpol	Port Neches, TX	372,200 (335,000)	
Copolymer Rubber	Baton Rouge, LA	138,900 (125,000)	
Dynagen, Inc.	Odessa, TX	100,000 (90,000)	
Firestone	Lake Charles, LA	166,600 (150,000)	
Goodyear	Houston, TX	338,900 (305,000)	
Goodyear	Beaumont, TX	22,200 (20,000)	
<u>Latex</u>			<u>Type of Latex</u>
Dow Chemical U.S.A.	Dalton, GA		
Dow Chemical U.S.A.	Freeport, TX		
Dow Chemical U.S.A.	Gales Ferry, CT	252,200 (227,000)	SB latex
Dow Chemical U.S.A.	Midland, MI		
Dow Chemical U.S.A.	Pittsburg, CA		
GenCorp	Howard, WI	40,000 (36,000)	SB latex
GenCorp	Mogadore, OH	101,100 (91,000)	SB latex; SBR latex; SBV latex
Goodyear	Akron, OH	4,400 (4,000)	SB latex; SBV latex
Goodyear	Calhoun, GA	55,500 (50,000)	SB latex; SBR latex; SBV latex
Goodyear	Houston, TX	28,900 (26,000)	SBR latex
Hampshire Chemical Corp.	Owensboro, KY	14,400 (13,000)	SB latex
BASF	Monaca, PA	25,500 (23,000)	SB latex
BASF	Chattanooga, TN	115,500 (104,000)	SB latex; SBR latex
Reichhold Chemicals, Inc.	Cheswold, DE	93,300 (84,000)	SB latex
Reichhold Chemicals, Inc.	Kensington, GA		
Rhône-Poulenc, Inc.	Gastonia, NC	25,600 (23,000)	SB latex
Rhône-Poulenc, Inc.	Charlotte, NC	30,000 (27,000)	SB latex
Rhône-Poulenc, Inc.	La Mirada, CA	13,300 (12,000)	SB latex
Rhône-Poulenc, Inc.	Kankakee, IL	10,000 (9,000)	SB latex

Source: Reference 29.

in Appendix C. In developing emission factors, the facilities were assumed to be operating at 80 percent production capacity.²⁷

Butadiene used in elastomer production is usually stored in pressurized vessels with some vented to a flare (point A in Figure 5-1). Storage, therefore, results in low emissions. Two facilities, however, store butadiene-containing material in fixed-roof storage tanks. Emissions are estimated to be low because of the low concentrations of butadiene (5 percent by weight or less).

Butadiene users do not transfer butadiene as a product onto tank trucks, so emissions from transfer operations are not of concern. Unloading emissions would be mostly emitted as storage tank working losses (already discussed under storage). Moving butadiene around within the plant is covered by equipment leak emission estimates.

Process Vent Emissions

As seen from the vent locations in Figure 5-1, process vent discharges occur from reactor vessels, recovery columns, and other process vessels. They may occur continuously (from a continuous process) or intermittently (from a batch process). Some continuous processes have emissions during startup and shutdown or during a control device malfunction or process upset.

The potential locations of these process vents (Vents B, C, D, F) are shown in Figure 5-1. Although the actual locations and butadiene content may vary depending on the facility design, process vents are typically located on absorption columns used to recover butadiene. In some cases, process vents are directed to other parts of the plant, or to a gas recovery system for use as fuel, rather than discharged to the atmosphere.

The available emissions data are presented in Table 5-3 as emission factor ranges. The facility emission factor range was calculated as described in Section 4.0 and reflects actual

TABLE 5-3. SUMMARY OF EMISSION FACTORS FOR SB COPOLYMER PRODUCTION FACILITIES^{a,b}
(FACTOR QUALITY RATING D)

Emission Sources	Facility Emission Factors		Uncontrolled Emission Factors	
	Range ^c	Mean	Range	Mean
Process Vents 3-01-026	0.00024 - 94.34 lb/ton (n=18) (0.00012 - 47.17 kg/Mg)	7.10 lb/ton (3.55 kg/Mg)	0.124 - 94.34 lb/ton (n=18) (0.062 - 47.17 kg/Mg)	14.20 lb/ton (7.10 kg/Mg)
Secondary Sources:				
Wastewater 3-01-026	0 - <10 lb/ton (n=18) (0 - <5 kg/Mg) ^d	0.30 lb/ton (0.15 kg/Mg)	---	---
Other liquid waste 3-01-026	<0.02 lb/ton (n=5) (<0.01 kg/Mg)	<0.02 lb/ton (<0.01 kg/Mg)	---	---
Solid waste 3-01-026	0 - <0.02 lb/ton (n=11) (0 - <0.01 kg/Mg) ^d	<0.02 lb/ton <0.01 kg/Mg	---	---

Source: Reference 27.

Note: Annual emissions from uncontrolled equipment leaks range 0.11 - 23.59 tons/yr (0.10 - 21.40 Mg/yr) and average 7.28 tons/yr (6.60 Mg/yr) (n=19).^{a,c}

^a Assumes production capacity of 80 percent.

^b Factors are expressed as lb (kg) butadiene emitted per ton (Mg) produced.

^c Ranges are based on actual emissions reported by the facilities. Thus, values include controls whenever they have been implemented.

^d Upper value used to prevent disclosing confidential operating capacity.

n = number of facilities.

NA = not available.

"---" means no data specific to level or efficiency of controls were available.

emissions and the various levels of control reported. The second emission factor range incorporates both emissions from existing uncontrolled sources and potential emissions from controlled sources with controls removed.²⁷

Although 20 facilities supplied emissions data (Table C-6), production capacities for two were not available; therefore, these two were omitted from the emission factor range development. Control devices in use include absorbers, boilers, flares, scrubbers, and pressure condensers. Emissions after controls (Vent E) were calculated by applying appropriate reduction efficiencies. Standard control efficiencies from Table 4-6 were used to calculate controlled emissions unless alternate values were supplied by the companies and accompanied by quantitative documentation.

Equipment Leak Emissions

Emissions occur from process equipment components whenever the liquid or gas process streams leak from the equipment. Butadiene emissions were estimated for the following equipment components: pump seals, process valves, compressors, safety relief valves (pressure devices), flanges, open-ended lines, and sampling connections. For each facility where the number of equipment components was known, emissions were estimated using emission rates presented in Table 4-7. The method is described further in Appendix D. Although these emission rates include an unknown level of control at butadiene producer, the only controls reported in use by the industry are flares and/or rupture discs for pressure relief devices (PRD). Some facilities perform visual inspections, but with an unknown frequency. These estimates may not represent emissions at SB copolymer facilities where control practices differ. A summary of the available data is given in Table 5-3.

Secondary Emissions

Secondary emissions occur at the on-site and off-site facilities that treat and dispose of wastewater, liquid waste, or solid waste. Waste streams may be generated from any of the operations shown in Figure 5-1. Emissions data are available for 18 of the 21 facilities,

TABLE 5-4. POLYBUTADIENE PRODUCTION FACILITIES

Company	Location	Capacity in 1993 tons/yr (Mg/yr)
American Synthetic Rubber	Louisville, KY	121,300 ^a (110,000) ^a
Bridgestone/Firestone	Orange, TX	132,300 (120,000)
Bridgestone/Firestone	Lake Charles, LA	--- ^b
Goodyear	Beaumont, TX	237,000 ^a (215,000) ^a
Polysar	Orange, TX	126,800 (115,000)

Source: References 12 and 30.

^a Total includes some multipurpose SBR.

^b Facility coproduces SB elastomer and polybutadiene rubber, but is primarily dedicated to SB elastomer.

but are incomplete for each type of waste stream. These data are summarized in Table 5-3. The emission factor estimates were calculated from information on the flowrate of butadiene (kg/day) in the stream and facility production. Because of butadiene's volatility and low solubility, no reduction was included unless butadiene vapors were routed to a control device.

5.2 POLYBUTADIENE PRODUCTION

Polybutadiene production consumes approximately 20 percent of the butadiene produced.⁸ Like SB elastomer, polybutadiene is primarily used by the tire manufacturing industry, but also finds uses in the high-impact resins industry.

Four companies at five U.S. locations currently have the capacity to produce polybutadiene, two of which coproduce polybutadiene with SB copolymer. These four companies are listed in Table 5-4.^{12,30} Firestone in Lake Charles is primarily an SB copolymer producer, therefore emissions from this facility were included in the preceding section. Only emissions attributed to the polybutadiene production process are presented in this section.

5.2.1 Process Description

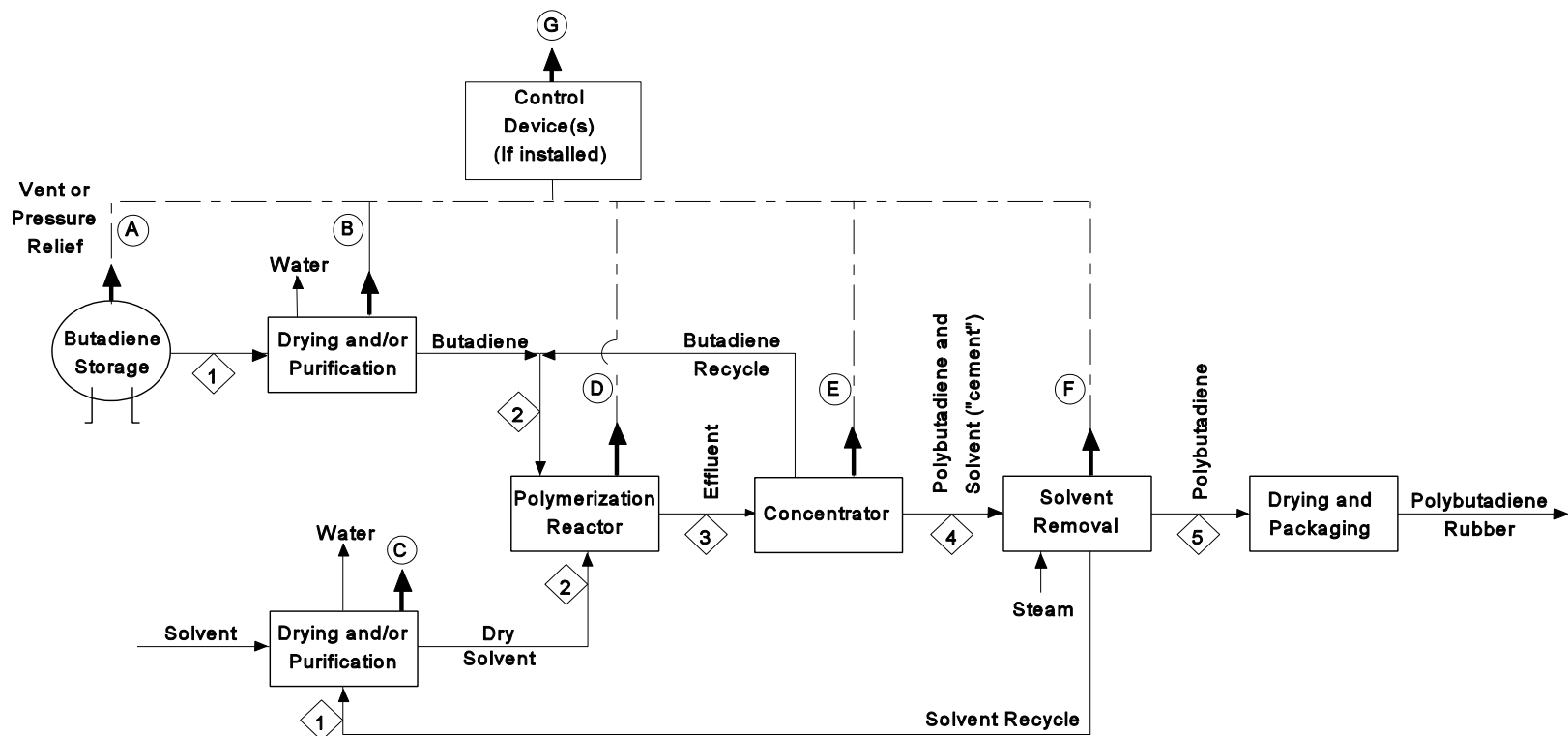
The polymerization of butadiene can yield several isomeric polymers. The two of commercial significance are the cis-1,4 isomer and, to a much lesser extent, the 1,2 isomer.³¹ The majority of polybutadiene is produced by a solution polymerization process. Smaller quantities are produced by an emulsion polymerization process. The relative proportions of the isomers formed are dependent on the catalyst system used and reaction conditions.

The cis-polybutadiene rubber process consists of five basic steps: (1) butadiene and solvent purification, (2) reaction, (3) concentrations, (4) solvent removal, and (5) drying and packaging. Figure 5-2 shows a diagram of this process.³¹ In Step 1, feed butadiene is dried and combined with a recycled butadiene stream. Solvent, typically hexane or cyclohexane, is also dried along with a recycled solvent stream. In Step 2, these streams are fed to the reactor, where polymerization takes place. With solution polymerization, a catalyst, such as lithium, sodium, or potassium, is used. The overall conversion of the process is greater than 98 percent.³¹

Reactor effluent is fed to the concentrator (Step 3), where any unreacted butadiene is removed for recycling. The product stream leaving the concentrator consists of polybutadiene dissolved in solvent, and is often referred to as "cement." The cement stream leaving the concentrator contains negligible butadiene. In Step 4, the cement is stripped of solvent, which is recycled to solvent purification. Stripping occurs through direct steam contact. The resulting polybutadiene crumb/water stream is dried, compressed, and packaged in Step 5. This process is run both continuously and in batch mode, but the majority of facilities operate continuously.

5.2.2 Emissions

Butadiene emissions from polybutadiene production are primarily of four types: process vent emissions, equipment leaks, secondary emissions, and accidental or emergency releases. Storage under pressure significantly reduces any potential for storage emissions



Source: Reference 31

Figure 5-2. Process Diagram for Production of Polybutadiene Rubber

(point A in Figure 5-2), although source emissions during handling and transport of raw material are possible. Each emission type is discussed separately below. Typical production for the industry is estimated at 81 percent of capacity.³¹ This is incorporated into the emission factor calculations.

Process Vent Emissions

Process vent emissions occur during purging of noncondensable gases from reactors and other process vessels. The emissions may occur continuously or intermittently. Emission points indicated in Figure 5-2 as Vents B through F give the possible vent locations for butadiene releases. Emissions after the control device are denoted as Vent G in the process diagram.

Data on 1984 emissions, both uncontrolled and controlled, and the control type and efficiency are available for each facility and are summarized as emission factor ranges in Table 5-5 (for raw data, see Tables C-9 and C-10 in Appendix C). The two ranges were developed to represent actual emissions, where existing controls are taken into account, and potential emissions, where all reported sources are treated as uncontrolled sources.

In 1984, all facilities but one were controlling process vent emissions. Four used at least a flare, and one also used a butadiene absorber. The fifth used a butadiene recovery system. Two facilities reported control efficiencies greater than 98 percent; however, 98 percent was used as an upper limit in the absence of test data to support the higher numbers.

Equipment Leak Emissions

Equipment leak emissions were estimated by using the number of components, their time in service, and the weight percent butadiene in the stream. Estimated emissions were derived by applying the CMA method described in Appendix D to the facility-specific data

TABLE 5-5. SUMMARY OF EMISSION FACTORS FOR POLYBUTADIENE PRODUCTION FACILITIES^{a,b}
(FACTOR QUALITY RATING U)

Emission Sources	Facility Emission Factors		Uncontrolled Emission Factors	
	Range ^c	Mean	Range	Mean
Process Vents 3-01-026	0.00008 - 36.06 lb/ton (n=6) (0.00004 - 18.03 kg/Mg)	6.14 lb/ton (3.07 kg/Mg)	0.0032 - 36.06 lb/ton (n=6) (0.0016 - 18.03 kg/Mg)	8.96 lb/ton (4.48 kg/Mg)
Secondary Sources:				
Wastewater 3-01-026	0 - 0.74 lb/ton (n=3) (0 - 0.38 kg/Mg)	0.24 lb/ton (0.12 kg/Mg)	0 - 0.74 lb/ton (0 - 0.38 kg/Mg)	0.24 lb/ton (0.12 kg/Mg)
Solid Waste 3-01-026	0 lb/ton (0 kg/Mg)	0 lb/ton (0 kg/Mg)	0 lb/ton (0 kg/Mg)	0 lb/ton (0 kg/Mg)

Source: Reference 31.

Note: Annual emissions from uncontrolled equipment leaks range from 4.04 - 31.42 tons/yr (3.66 - 28.50 Mg/yr) and average 10.41 tons/yr (9.44 Mg/yr) (n=6).^a For the facilities that reported emissions, none control equipment leaks.

^a Assumes production capacity of 81 percent.

^b Factors are expressed as lb (kg) butadiene emitted per ton (Mg) produced.

^c Ranges are based on actual emissions reported by the facilities. Thus, values include controls whenever they have been implemented.

n = number of facilities.

given in Appendix C, Table C-11, and component-specific emission factors from Table 4-7. These results are summarized in Table 5-5. They represent some level of control because the average emission rate is based on practices at butadiene producers. Although some facilities perform visual monitoring, none gave a specific frequency or scope of these programs; therefore, no estimate of reductions could have been made. A comparison to practices at butadiene producers was also not possible; therefore, users of the estimate should take this uncertainty into account.

Secondary Emissions

Only one facility reported a wastewater stream containing butadiene. Complete evaporation of butadiene from this stream, which is sent to a lagoon, was assumed because of butadiene's volatility and low water solubility. Secondary emissions are summarized in Table 5-5. One other facility reports that its wastewater contains no butadiene and, therefore, produces no emissions. One of the three facilities that indicated that they generate solid waste estimated that no butadiene emissions are released. Table C-12 in Appendix C summarizes the facility-specific data.

Accidental Release Emissions

Accidental release emissions include pressure relief events and accidental releases. Two of the four facilities reported no accidental release emissions; each of the other two facilities reported one accidental release. In the first case, the release was a result of a cracked valve; in the second, a loose flange. The estimated losses were 2,998 pounds (1,360 kg) over 30 hours and 11 pounds (5 kg) over 5 minutes, respectively.³²

5.3 ADIPONITRILE PRODUCTION

Adiponitrile (hexanedinitrile) is primarily used as an intermediate in the manufacture of hexamethylenediamine (HMDA) (1,6-diaminohexane), a principal ingredient in nylon 6,6 production.³³ Three facilities currently produce adiponitrile; Table 5-6 identifies their locations and capacities.²⁹ Only two facilities use butadiene, accounting for 12 percent of butadiene use in the United States.¹⁰ Monsanto uses acrylonitrile as the starting material and is, therefore, not a source of butadiene emissions and is omitted from further discussion.

5.3.1 Process Description

Both facilities that use butadiene run the adiponitrile process on a continuous basis. A generalized process diagram (Figure 5-3) illustrates the steps in adiponitrile production.³⁴ Butadiene is first converted to pentenenitriles by the addition of hydrogen cyanide in the presence of a catalyst (Step 1). The resulting pentenenitriles stream then continues through the butadiene column (Step 2) and catalyst removal (Step 3). The intermediary may be sold commercially or refined further. On-site processing begins with distillation of the pentenenitriles for use in dinitrile synthesis (Step 4). In the dinitrile system unit (Step 5), the mononitriles are further hydrocyanated for conversion to dinitriles. The resulting mixture of six-carbon dinitriles is refined by distillation (Step 6). The final product, adiponitrile, is stored in tanks and then pumped via pipeline to the HMDA unit for hydrogenation. Most of the by-products of the process are burned in a boiler to recover their heating value. One of the mononitrile by-products is sold as a commercial product.

5.3.2 Emissions

From facility information, the sources of butadiene emissions are associated with production up to the point of catalyst removal. Test data of the butadiene column bottoms (at one location) show less than 0.02 percent by weight of butadiene.³⁴ The emission source types for which there are data include the process vents (denoted Vents B and C in Figure 5-3), equipment leaks, secondary sources, and one estimate of losses during butadiene storage railcar

TABLE 5-6. ADIPONITRILE PRODUCTION FACILITIES

Facility	Location	Capacity in 1993 tons/yr (Mg/yr)
DuPont	Orange, TX	244,400 (220,000)
DuPont	Victoria, TX	238,900 (215,000)
Monsanto ^a	Decatur, GA	228,900 (206,000)



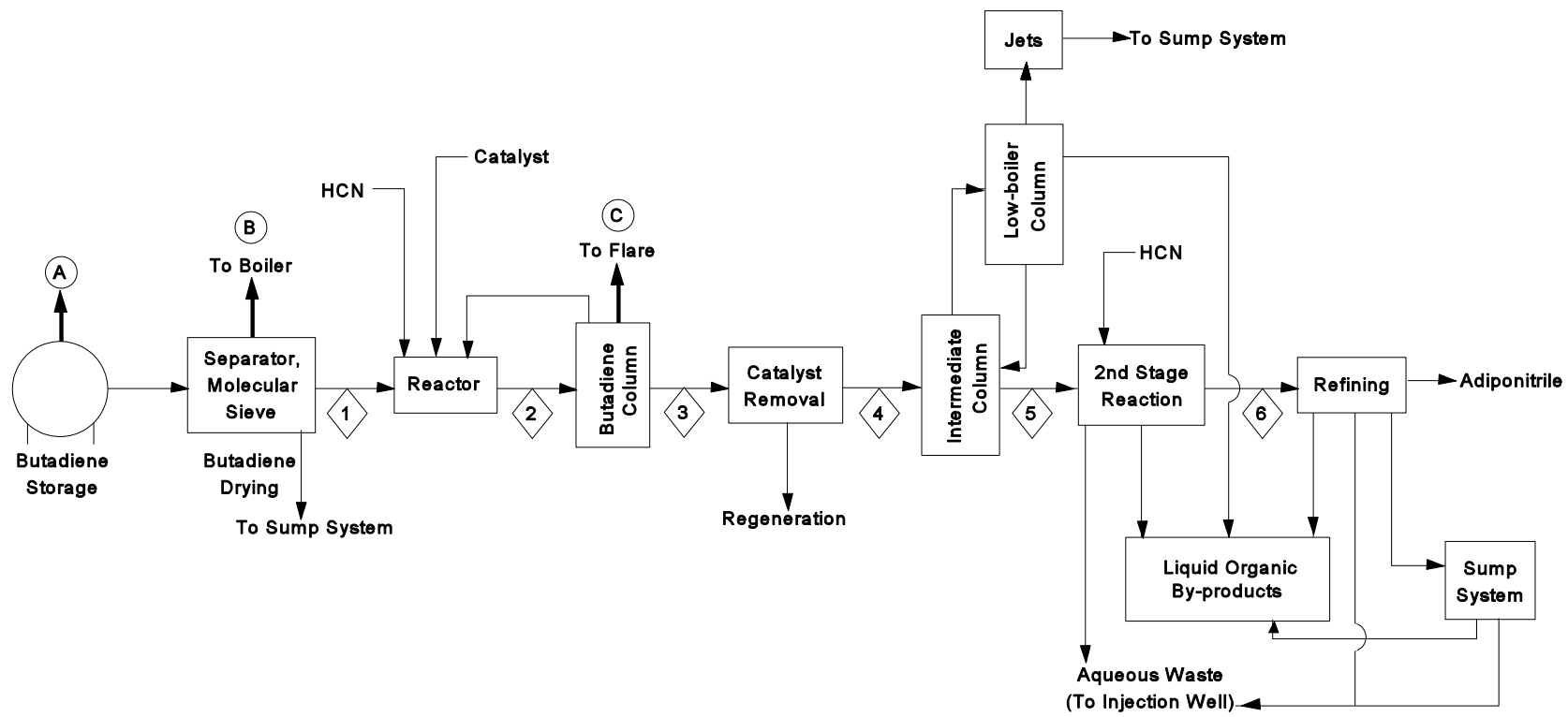
Source: Reference 29.

^a Monsanto does not use butadiene as a raw material.

unloading at the facility. Other typical sources include emergency or accidental releases and emissions associated with butadiene storage (Vent A). No data are available for accidental releases and, because butadiene is stored under pressure, storage losses are assumed to be a small source of emissions. In order to develop emission factors, production values were needed. In the absence of facility-specific information, 80 percent of literature capacity values were assumed to represent production.³⁵

Process Vent Emissions

The emissions reported by the two facilities for process vents are given in Table 5-7 as emission factor ranges. All are controlled either by using a flare or by routing emissions to a boiler (see Tables C-13 and C-14 in Appendix C). Thus, facility emission factors represent controlled emissions. The uncontrolled emission factors represent potential emissions for the sources reported. Flares were assigned a 98-percent maximum removal efficiency unless supplementary data supported higher efficiencies. Because butadiene content in the process beyond the catalyst removal stage is low, emissions from process vents downstream of this stage were expected to be negligible.



Source: Reference 34

Figure 5-3. Process Diagram for Production of Adiponitrile

TABLE 5-7. SUMMARY OF EMISSION FACTORS FOR ADIPONITRILE PRODUCTION FACILITIES^{a,b}
(FACTOR QUALITY RATING U)

Emission Sources	Facility Emission Factors		Uncontrolled Emission Factors	
	Range ^c	Mean	Range	Mean
Process Vents 3-01-254	0.12 lb/ton (n=2) (0.06 kg/Mg)	0.12 lb/ton (0.06 kg/Mg)	5.84 - 6.30 lb/ton (n=2) (2.92 - 3.15 kg/Mg)	6.08 lb/ton (3.04 kg/Mg)
Secondary Sources 3-01-254	0.016 - 0.024 lb/ton (n=2) (0.008 - 0.012 kg/Mg)	0.02 lb/ton (0.01 kg/Mg)	0.016 - 0.024 lb/ton (n=2) (0.008 - 0.012 kg/Mg)	0.02 lb/ton (0.01 kg/Mg)

Source: Reference 35.

Note: Annual emissions from uncontrolled equipment leaks (SCC 3-01-254-20) range 2.72 - 5.25 tons/yr (2.47 - 4.76 Mg/yr) and average 3.99 tons/yr (3.62 Mg/yr) (n=2).^{a,b}

^a Assumes production capacity of 80 percent.

^b Factors are expressed as lb (kg) butadiene emitted per ton (Mg) produced. Only incomplete data on emissions were available, therefore, values underestimate emissions.

^c Ranges are based on actual emissions reported by the facilities. Thus, values include controls whenever they have been implemented.

n = number of facilities.

NA = not available.

Equipment Leak Emissions

Equipment leak emissions were estimated by using the number of components, their time in service, and the weight percent butadiene in the stream. Estimated emissions were derived by applying the CMA method described in Appendix D to the facility-specific data given in Appendix C, Table C-11, and component-specific emission factors from Table 4-7. These results are summarized in Table 5-7. They represent some level of control because the average emission rate is based on practices at butadiene producers. Controls in use by the two facilities include ambient monitoring, quarterly leak detection and repair, double mechanical seals, and pressure relief devices, some of which are routed to a flare. No comparison to practices at butadiene producers is possible, however, so the user of the estimate should take this uncertainty into account.

Other Emissions

Although both facilities list various secondary sources, only two of the emission values are given, one for wastewater, the second for a waste tank (see Table C-16 in Appendix C). Emissions from these sources are reported to be uncontrolled. Other secondary sources reported include butadiene separator blowdown water, waste liquids, and a sump tank. Emissions from the latter two are routed to a boiler. Another source identified is the unloading of a storage railcar with a closed vapor balance system, estimated to emit 9.6 tons/yr (8.7 Mg/yr).

5.4 NEOPRENE PRODUCTION

Neoprene, also called polychloroprene, is a product of chloroprene (2-chloro-1,3-butadiene) polymerization. Consuming approximately 5 percent of butadiene produced,⁸ neoprene rubber is primarily used in the automotive industry in such applications as belts, cables, hoses, and wires.³⁶ Three facilities currently produce neoprene; these are listed in Table 5-8, along with 1993 capacities.²⁹ Only two facilities use butadiene as a raw material.

TABLE 5-8. CHLOROPRENE/NEOPRENE PRODUCTION FACILITIES

Company	Location	Capacity in 1993 tons/yr (Mg/yr)
DuPont	Louisville, KY ^a	151,100 (136,000)
DuPont	La Place, LA	
Polysar	Houston, TX	30,000 (27,000)

Source: Reference 30.

^aThis facility does not use butadiene as the raw material. The facility also has an additional 44,000 tons (39,900 Mg) of idle capacity, which does not use any butadiene either.

Because the DuPont plant in Louisville, Kentucky, starts with chloroprene, it is not included in the subsequent discussion of process and emissions information.²⁹

5.4.1 Process Description

The production of neoprene is a continuous process that starts with the chlorination of butadiene to form chloroprene. Figure 5-4 shows this process schematically.³⁷ The initial chlorination (Step 1) takes place in a vapor-phase reactor. This produces a mixture of 3,4-dichloro-1-butene (3,4-DCB) and the cis and trans isomers of 1,4-dichloro-2-butene (1,4-DCB), along with unreacted butadiene. The next process step (Step 2) involves the isomerization of 1,4-DCB to 3,4-DCB and the removal of any unreacted butadiene. This is performed in a combined reactor/distillation column under reduced pressure and the presence of a catalyst. Butadiene is recycled to the chlorinator and 1,4-DCB can be recycled or used elsewhere.

The final steps in the synthesis of chloroprene involve the dehydrochlorination of 3,4-DCB in a solution of sodium hydroxide and water (Step 3) and further refining (Step 4). The chloroprene is isolated from the unreacted 3,4-DCB, which is recycled to the reactor. The overall chemical yield of chloroprene is generally greater than 95 percent.³⁸

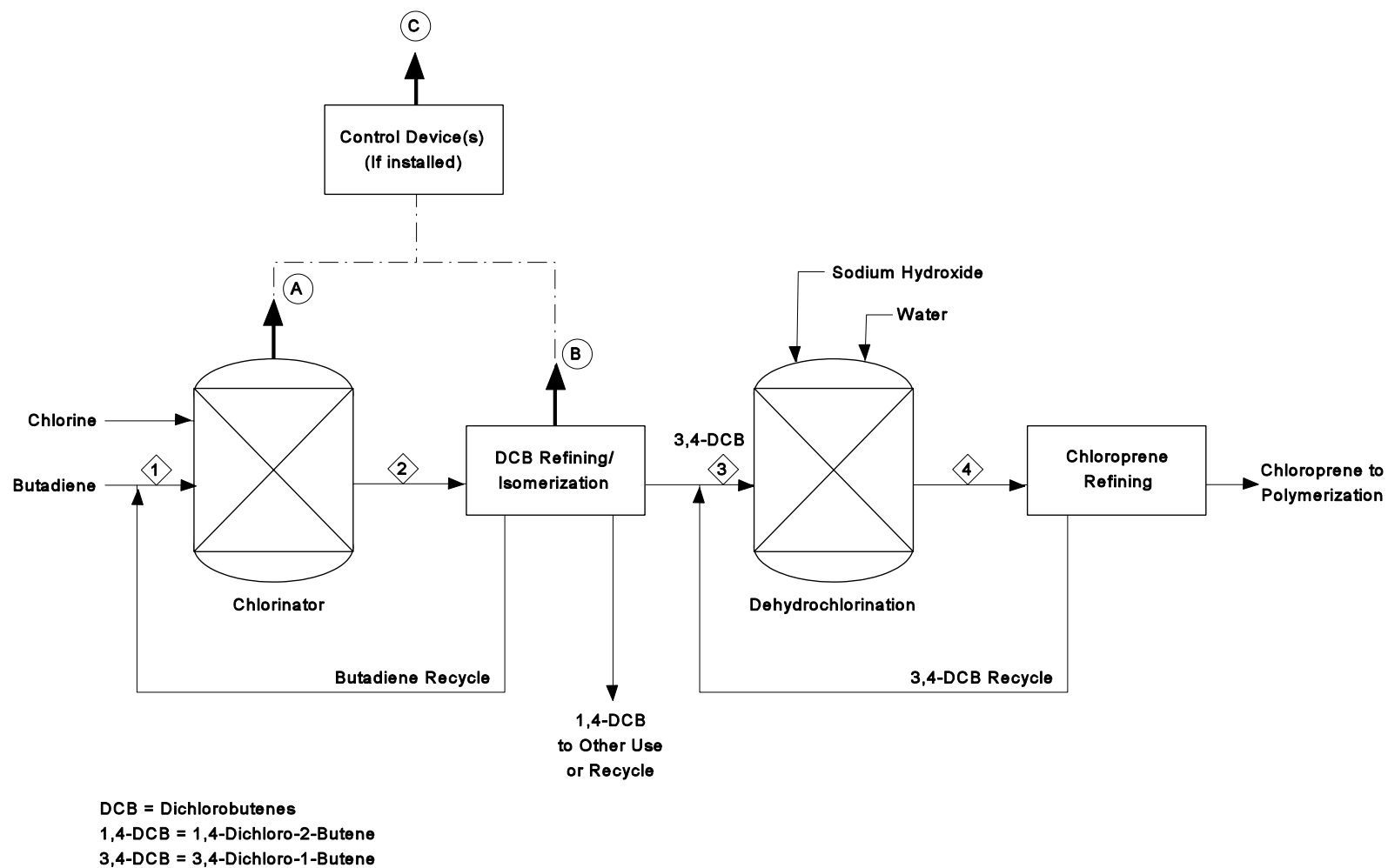


Figure 5-4. Process Diagram for Production of Chloroprene Monomer

Source: Reference 37

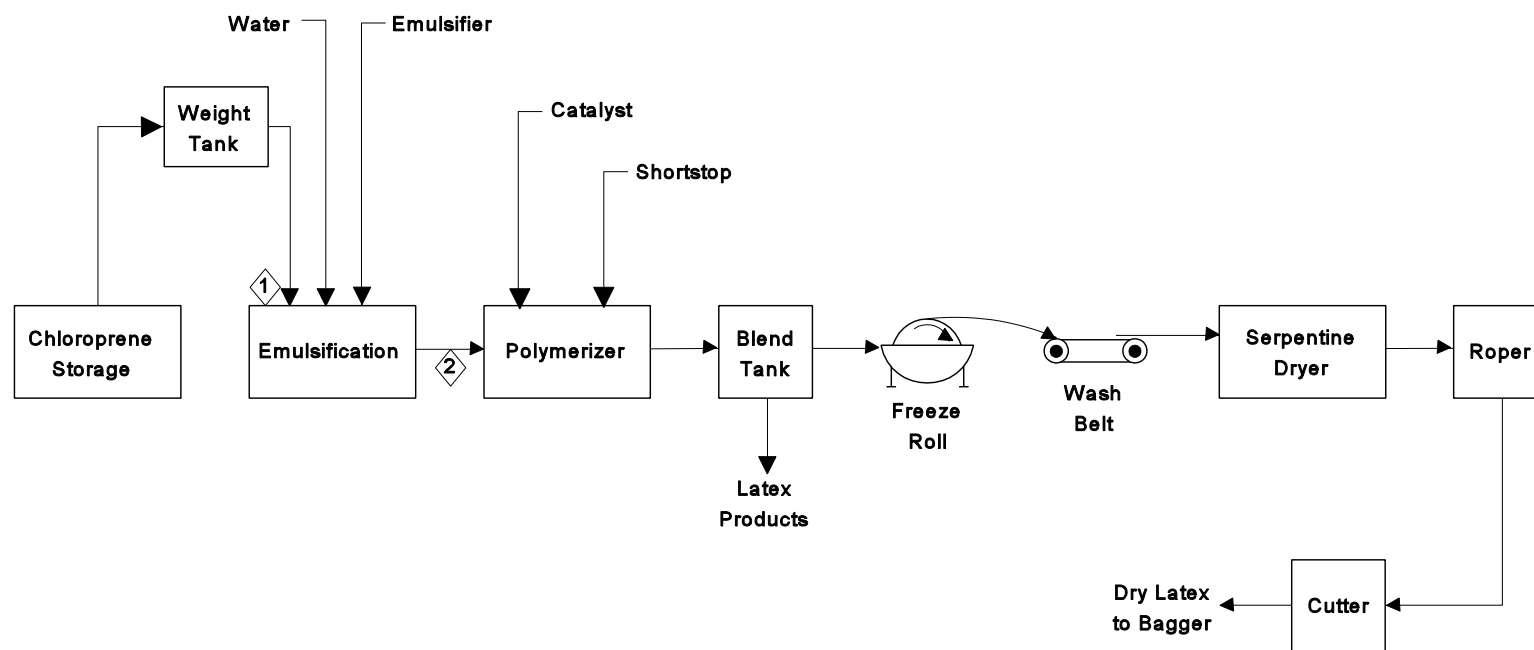
The chloroprene produced is then used in the production of neoprene elastomers. A schematic of this process is shown in Figure 5-5.³⁹ Chloroprene proceeds to emulsification (Step 1), then to initiation, catalysis, and monomer conversion in Step 2. The polymer continues with short-stopping and stabilization, monomer recovery, and polymer isolation. The resulting latex can be sold as product or dried and compressed to form neoprene rubber.³⁹

5.4.2 Emissions

Of the five general emission types, information is only available for three: process vent releases, equipment leaks, and emergency and accidental release emissions. These sources are discussed in more detail below. Although secondary sources and storage-related emissions were not characterized, butadiene emissions from pressurized storage tanks were assumed to be negligible. Some losses during transfer and handling are likely. For purposes of emission factor development, both facilities were assumed to be operating at full capacity.³⁹

Process Vent Emissions

The two facilities using butadiene report that process vent emissions are limited to the chloroprene production process. These vents are associated with the chlorination, DCB refining, and isomerization steps (identified as Vents A and B in Figure 5-4) and are used to vent noncondensable gases such as nitrogen. Unreacted butadiene is removed after chlorination is complete and, therefore, is only present in low quantities in subsequent process steps. A summary of the data collected in 1985 appears in Table 5-9. The raw data are shown in Tables C-17 and C-18 in Appendix C. Calculated as described in Section 4.0, the facility emission factor range reflects the use of some controls by both facilities. The uncontrolled emission factor ranges represent potential emissions if the sources reported were not controlled.



Source: Reference 39

Figure 5-5. Flow Sheet for the Production of Neoprene

TABLE 5-9. SUMMARY OF EMISSION FACTORS FOR NEOPRENE PRODUCTION FACILITIES^{a,b}
(FACTOR QUALITY RATING E)

Emission Sources	Facility Emission Factors		Uncontrolled Emission Factors	
	Range ^c	Mean	Range	Mean
Process Vents 3-01-026	0.32 - 6.78 lb/ton (n=2) (0.16 - 3.89 kg/Mg)	4.04 lb/ton (2.02 kg/Mg)	0.40 - 24.18 lb/ton (n=2) (0.20 - 12.09 kg/Mg)	12.28 lb/ton (6.14 kg/Mg)
Secondary Sources 3-01-026	NA	NA	NA	NA

Source: Reference 39.

Note: Annual emissions from uncontrolled equipment leaks range 1.03 - 4.88 tons/yr (0.93 - 4.43 Mg/yr) and average 2.95 tons/yr (2.68 Mg/yr) (n=2).^a For the facilities that reported emissions, none control equipment leaks.

^a Assumes production capacity of 100 percent.

^b Factors are expressed as lb (kg) butadiene emitted per ton (Mg) produced.

^c Ranges are based on actual emissions reported by the facilities. Thus, values include controls whenever they have been implemented.

n = number of facilities.

NA = not available.

Both facilities use controls, but the water-cooled condenser at one facility affords no emissions reduction. Also, the control efficiency of a flare in use was assigned a 98-percent removal efficiency, despite a higher value reported, because of the lack of supporting test data. Emissions from control devices are identified as Vent C on the process diagram.

Equipment Leak Emissions

Using facility-supplied information on the number of equipment components and the CMA procedure in Appendix D, equipment leak emissions estimates were calculated (see Table C-18 in Appendix C) and are summarized in Table 5-9. Although both facilities perform visual and area monitoring, neither provided specific information about these programs. No other controls were reported to be in use. The estimates include some level of control because the average emission rates are based on practices at butadiene producers.

Short-term Emissions

As a result of specific requests by the EPA for emissions data, short-term emissions are relatively well characterized. The data fall into four categories: short-term process vent emissions, pressure relief events, short-term emissions from equipment openings, and emissions from accidental releases.³⁷ No emissions were routed to a control device. A summary of the estimated emissions is given in Table 5-10.³⁷ Additional emissions are possible because companies were only asked to report the larger releases for that year.

5.5 ACRYLONITRILE-BUTADIENE-STYRENE COPOLYMER PRODUCTION

Acrylonitrile-butadiene-styrene (ABS) resins are currently produced by four companies at 10 locations.¹⁴ Table 5-11 presents a list of these facilities with their approximate capacities.²⁹ At least four of the ten facilities producing ABS do not use butadiene. They start instead from polybutadiene and proceed either through the suspension process or the continuous mass process. Therefore, no butadiene emissions are expected from these production processes.

TABLE 5-10. SHORT-TERM EMISSIONS FROM NEOPRENE PRODUCTION FACILITIES

Facility	Event Description	Number of Events per Year	Duration (minutes)	Amount Released per Event lb (kg)
Polysar	Butadiene vent shutdown	1	30	150 (68)
	Chlorinator shutdown	4/month	30	24 (11)
	Chlorinator shutdown	2/month	30	51 (23)
	Pressure relief	0	---	---
	Equipment opening	1	Unknown	<150 (<68)
	Accidental releases	0	---	---
DuPont	Vent	1	360	291 (132)
	Caustic scrubber relief valve	1	Unknown	40 (18)
	Equipment opening	0	---	---
	Accidental releases	0	---	---

Source: Reference 37.

ABS resins are used to make plastic components for a variety of uses, including automotive parts, pipe and fittings, appliances, telephones, and business machines. Butadiene use in resin production accounts for about 5 percent of total butadiene consumption.⁸

5.5.1 Process Description

ABS resins are synthesized by three polymerization processes: an emulsion process, a suspension process, and a continuous mass (bulk) process.⁴⁰ The majority of production is done by batch emulsions. Specialized resins are produced by the suspension process. These two processes are based on an aqueous-phase reaction. In contrast, the continuous mass process, the newest technology, does not proceed in water. This eliminates the need for dewatering and polymer drying, and reduces the volume of wastewater treatment required.

TABLE 5-11. ACRYLONITRILE-BUTADIENE-STYRENE RESIN
PRODUCTION FACILITIES

Company	Location	Capacity in 1993 tons/yr (Mg/yr)
GE	Washington, WV	133,300 (120,000)
GE ^a	Ottowa, IL	173,300 (156,000)
GE	Port Bienville, MS	101,100 (91,000)
Dow ^a	Midland, MI	71,100 (64,000)
Dow	Hanging Rock, OH	45,600 (41,000)
Dow ^a	Allyn's Point, CT	30,000 (27,000)
Dow ^a	Torrance, CA	20,000 (18,000)
Monsanto	Addyston, OH	226,700 (204,000)
Monsanto	Muscatine, IA	75,600 (68,000)
Diamond Polymers	Akron, OH	8,900 (8,000)

Source: Reference 29.

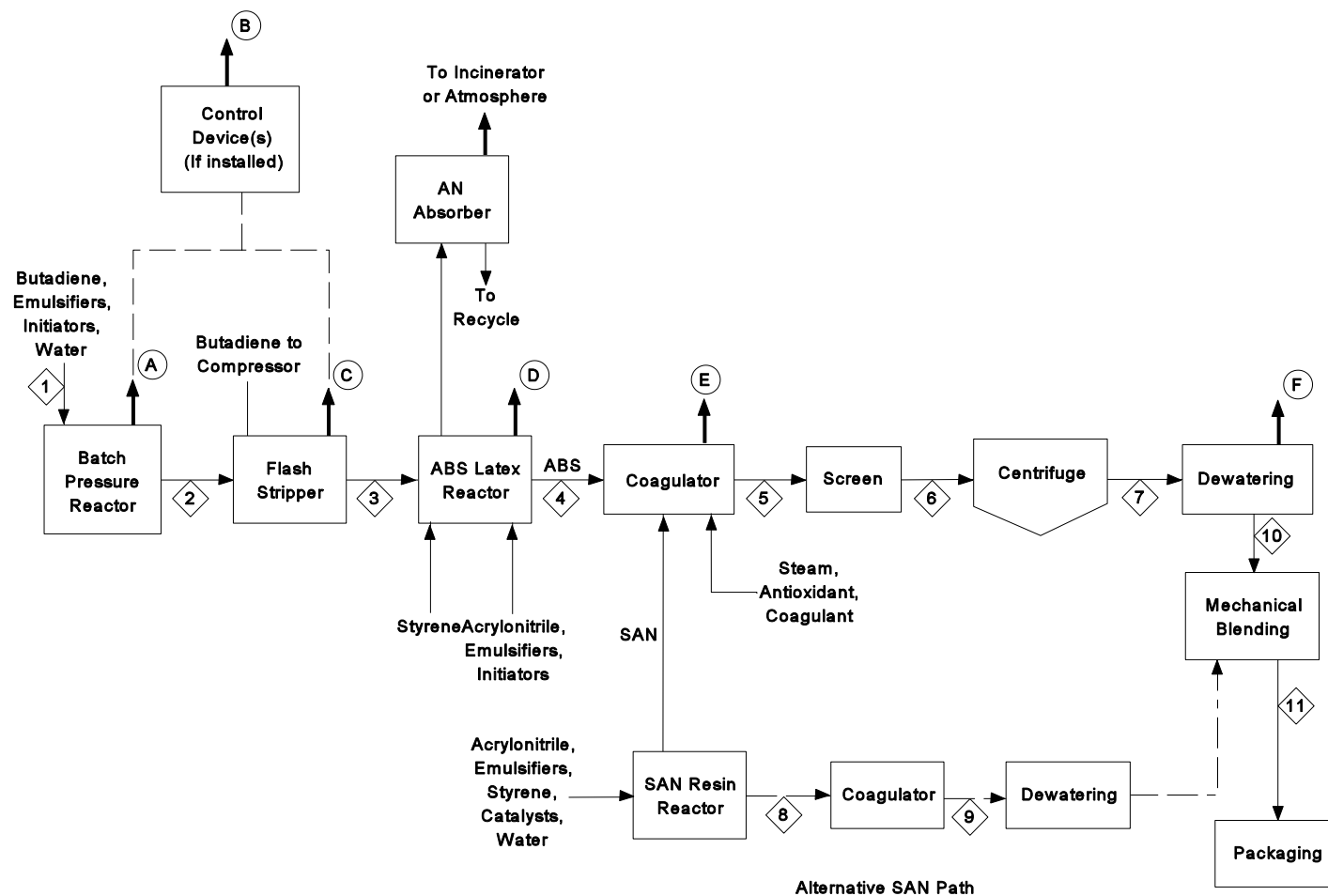
^a Facility has used polybutadiene as raw material for ABS production since 1985.

Emulsion Process

A block diagram of the ABS emulsion process is shown in Figure 5-6.⁴¹ This process is referred to as the ABS/styrene-acrylonitrile (ABS/SAN) process because SAN is prepared in a side step and mixed with graft ABS. Some companies also produce SAN as a separate product.

The emulsion process involves several steps, from combining the raw materials with water for aqueous-phase reaction to purification and packaging of the product resins. Three distinct polymerizations occur in the first few steps: (1) butadiene polymerizes to form a polybutadiene substrate latex; (2) styrene and acrylonitrile are grafted to the polybutadiene substrate; and (3) styrene-acrylonitrile copolymer forms.

About 70 to 90 percent of butadiene monomer is converted to polybutadiene in the first step (Figure 5-6). The unreacted butadiene monomer is removed from the latex in a



Source: Reference 41

Figure 5-6. Process Diagram for Production of ABS/SAN Via the Emulsion Process

flash stripper (Step 2) and usually recovered. The reactor, stripper, and recovery system vents are usually directed to a flare or other combustion device. The grafting of acrylonitrile and styrene to the polybutadiene substrate (Step 3) may be either a batch or continuous process. Reaction conversion of monomers is 90 to 95 percent. Vapors from the reactors are usually vented to an acrylonitrile absorber. The absorber is vented to the atmosphere or to an incinerator.

The ABS plastic is a blend of graft ABS rubber and SAN resin. The blend of these compounds determines the properties for the ABS product. The copolymer SAN is prepared in a separate side step. The prepared SAN and graft ABS are mixed at either of two points in the process. The SAN latex may be blended with graft rubber latex in the coagulator (Step 4). The agglomerated polymer is dewatered by screening (Step 5), centrifuging (Step 6), and vacuum filtration (Step 7). No drying step is required. However, some facilities employ a dryer in place of the centrifuge and vacuum filter.

Alternatively, the SAN latex may be coagulated (Step 8) and dewatered (Step 9) separately, with the resulting solid resins being mechanically mixed with ABS rubber (Step 10). In a compounding step, solids are mechanically blended with dyes, antioxidants, and other additives (Step 10). In the final step (11), the polymer sheets from these operations are pelletized and packaged.

Suspension Process

A block diagram of the suspension ABS process is shown in Figure 5-7.⁴¹ This process begins with polybutadiene rubber, which is so lightly cross-linked that it is soluble in the acrylonitrile and styrene monomers. Polybutadiene synthesis is previously described in this section.

Polybutadiene is first dissolved in styrene and acrylonitrile monomers to produce a solution free of cross-linked rubber gels. A free radical is added to the solution along with chain-transfer agents in a prepolymerizer (Step 2). After 25 to 35 percent monomer conversion,

the polymer syrup is transferred to a suspension reactor, where it is dispersed in water with agitation (Step 3).

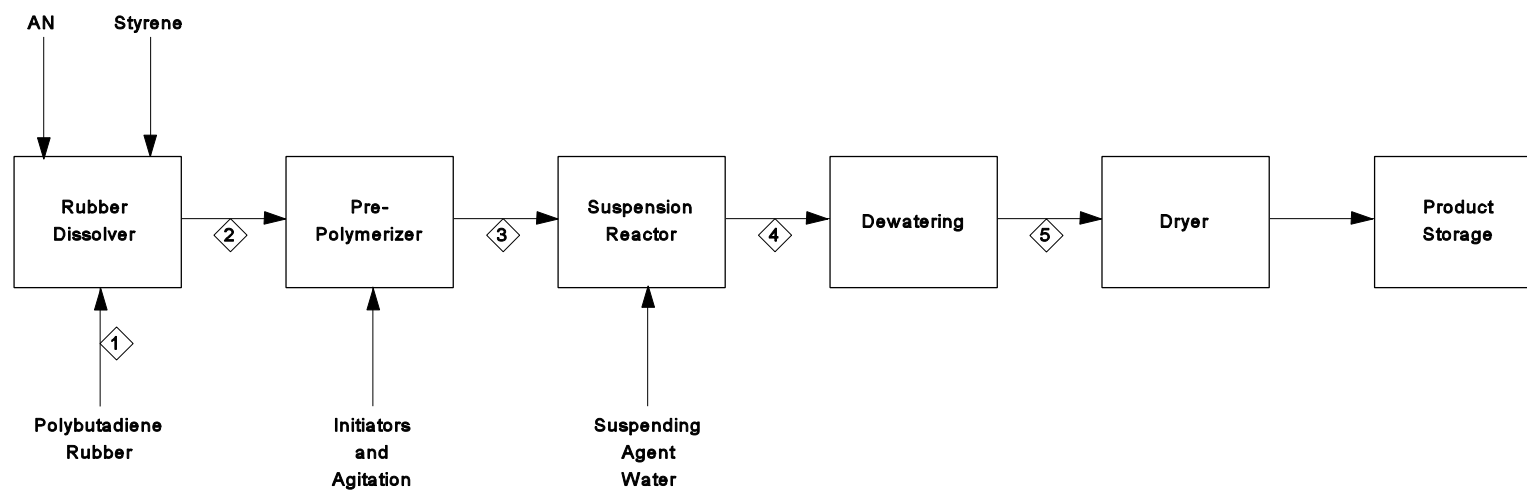
After achieving the desired monomer conversion, the products are transferred to a washing/dewatering system (Step 4), usually a continuous centrifuge. The polymer beads are then dried in a hot-air dryer (Step 5).

Continuous Mass Process

A block flow diagram for the continuous mass ABS process is shown in Figure 5-8.⁴¹ This process begins with polybutadiene rubber, which is dissolved in styrene and acrylonitrile monomers (Step 1), along with initiators and modifiers. The ABS polymer is then formed through phase inversion. Conversion begins in the prepolymerizer (Step 2), where the reaction causes the ABS rubber to precipitate out of solution. When monomer conversion is about 30 percent complete, the resulting syrup is transferred to the bulk polymerizer, where monomer conversion is taken to between 50 and 80 percent (Step 3). Unreacted monomer is removed under vacuum from the polymer melt in the devolatilizer (Step 4). The monomer vapors are condensed and recycled to the prepolymerizer. The ABS polymer is then extruded, cooled in a water bath (Step 5), and chopped into pellets (Step 6).

5.5.2 Emissions

As mentioned previously, at least four of the ten facilities producing ABS do not use butadiene. They start instead from polybutadiene and proceed either through the suspension process or the continuous mass process. Therefore, no butadiene emissions are expected from these production processes. Of the four remaining plants in operation, data are only available for three locations and are limited to information on process vents and equipment leaks associated with the emulsion process. Calculated emission factors are summarized in Table 5-12 as ranges and are based on data from 1984 appearing in Tables C-19 and C-20 in Appendix C.



Source: Reference 41

Figure 5-7. Process Diagram for Production of ABS via the Suspension Process
(not a source of butadiene emissions)

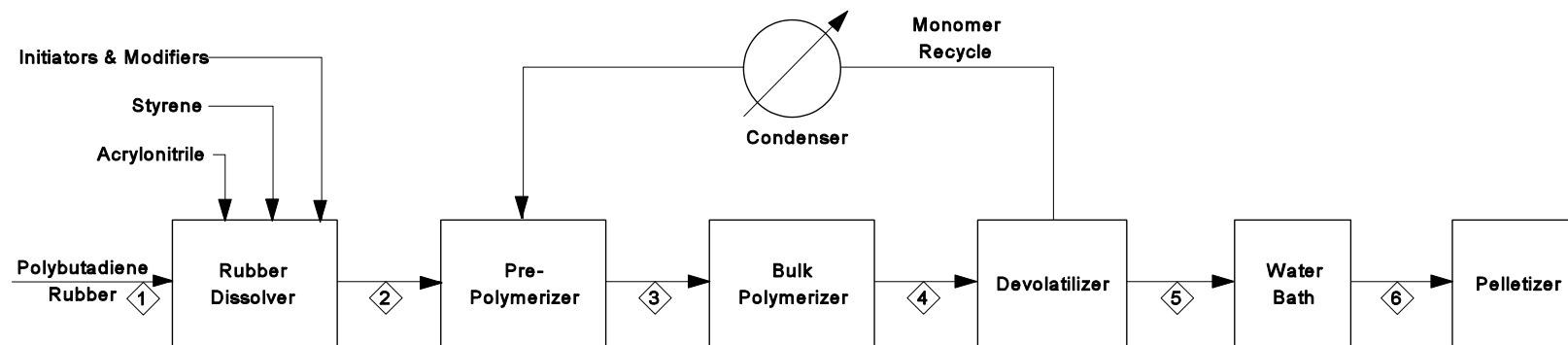


Figure 5-8. Process Diagram for Production of Bulk ABS
(not a source of butadiene emissions)

Source: Reference 41

The facility emission factor range for process vents includes existing sources, some of which are controlled. The uncontrolled range represents potential emissions if the sources reported were not controlled.⁴⁰

One estimate of emissions from butadiene storage was reported as zero because butadiene is stored under pressure. Some emissions are possible from secondary sources, emergency and accidental releases, and transfer and handling raw material losses, but estimates for these sources are currently unavailable.

Process Vent Emissions

Based on available data, process vent emissions of butadiene occur mainly from the flash-stripping of the latex from the polymerization reactor in the ABS emulsion process. The vent emissions from the batch reactors are highly variable, with changing compositions. Most of these vents are controlled by a flare (control efficiency of 99.9 percent).

Butadiene emissions also occur during the coagulation and dewatering stages and from intermediate process latex tanks. In 1984, only one facility used a control device. In this plant, one of the downstream vents was controlled by routing the vent to the plant boiler. Figure 5-6 shows the process vent locations: Vents A and C through F for emissions directly associated with the process and Vent B for emissions from a control device.

Equipment Leak Emissions

The estimates for uncontrolled equipment leaks at the two facilities appearing in Table 5-12 are based on equipment counts provided by the facilities. The CMA estimation procedure is described in Appendix D. One location reported daily inspection of equipment; however, no further details on follow-up for any leaks discovered during these inspections were given. The estimates include some level of control because the average emission rates are based on practices at butadiene producers.

TABLE 5-12. SUMMARY OF EMISSION FACTORS FOR ABS PRODUCTION FACILITIES,
EMULSION PROCESS^{a,b}
(FACTOR QUALITY RATING E)

Emission Sources	Facility Emission Factors		Uncontrolled Emission Factors	
	Range ^c	Mean	Range ^c	Mean
Process Vents 6-41	0.16 - 10.66 lb/ton (n=3) (0.08 - 5.33 kg/Mg)	4.22 lb/ton (2.11 kg/Mg)	6.50 - 11.28 lb/ton (n=3) (3.25 - 5.64 kg/Mg)	9.48 lb/ton (4.74 kg/Mg)
Secondary Sources 6-41	NA	NA	NA	NA

Source: Reference 40.

Note: Annual emissions from uncontrolled equipment leaks range from 1.21 - 3.50 tons/yr (1.10 - 3.17 Mg/yr) and average 2.36 tons/yr (2.14 Mg/yr) (n=2).^a For facilities that reported emissions, none control equipment leaks.

^a Assumes production capacity of 100 percent.

^b Factors are expressed as lb (kg) butadiene emitted per ton (Mg) produced. Data from two facilities are specific to the emulsion process; the third is assumed to use the same.

^c Ranges are based on actual emissions reported by the facilities. Thus, values include controls whenever they have been implemented.

n = number of facilities.

NA = not available.

5.6 NITRILE ELASTOMER PRODUCTION

Nitrile elastomer or nitrile-butyl rubber (NBR) is produced by nine facilities.²⁹ The location of the facilities, the type of elastomer produced, and their approximate capacities are presented in Table 5-13.²⁹

Nitrile elastomer is considered a specialty elastomer and is primarily used for its oil-, solvent-, and chemical-resistant properties by a variety of manufacturers.⁴² Some uses include hose, belting, and cable manufacturing, and molded goods such as seals and gaskets. Nitrile elastomer production accounts for about 5 percent of total annual butadiene consumption.⁸

Several of the facilities involved in NBR production also produce other elastomers. Goodyear in Texas, Polysar in Tennessee and Texas, Copolymer, and Reichhold all produce SB copolymers. Because of the common use of butadiene in these production processes, emissions data often represent total rather than individual process emissions. Whenever possible, the portion of butadiene emissions directly attributable to nitrile rubber is shown.

5.6.1 Process Description

Nitrile elastomers are copolymers of acrylonitrile and butadiene. They are produced by emulsion polymerization in batch or continuous processes. The process is illustrated in the block flow diagram in Figure 5-9.⁴¹

The emulsion polymerization process uses water as a carrier medium. Butadiene and acrylonitrile monomers are piped to agitated polymerization reactors (Step 1) along with additives and soap. The water not only serves as a reaction medium, but also effectively transfers the heat of reaction to the cooled reactor surfaces. The additives include a catalyst

TABLE 5-13. NITRILE ELASTOMER PRODUCTION FACILITIES

Company	Location	Elastomer Type	Capacity in 1993 dry rubber or latex tons/yr (Mg/yr)
Copolymer	Baton Rouge, LA	Solid rubber	11,100 (10,000)
Zeon Chemicals	Pasadena, TX	Hydrogenated	2,200 (2,000)
	Louisville, KY	Solid rubber	33,300 (30,000)
Goodyear	Houston, TX	Solid rubber	34,400 (31,000)
Polysar Ltd.	Orange, TX	Solid rubber	2,200 (2,000)
BASF	Chattanooga, TN	Latex	--
Reichhold Chemicals	Cheswold, DE	Latex	--
Uniroyal Chemical Co.	Painesville, OH	Solid rubber	22,200 (20,000)
W. R. Grace	Owensboro, KY	Latex	--

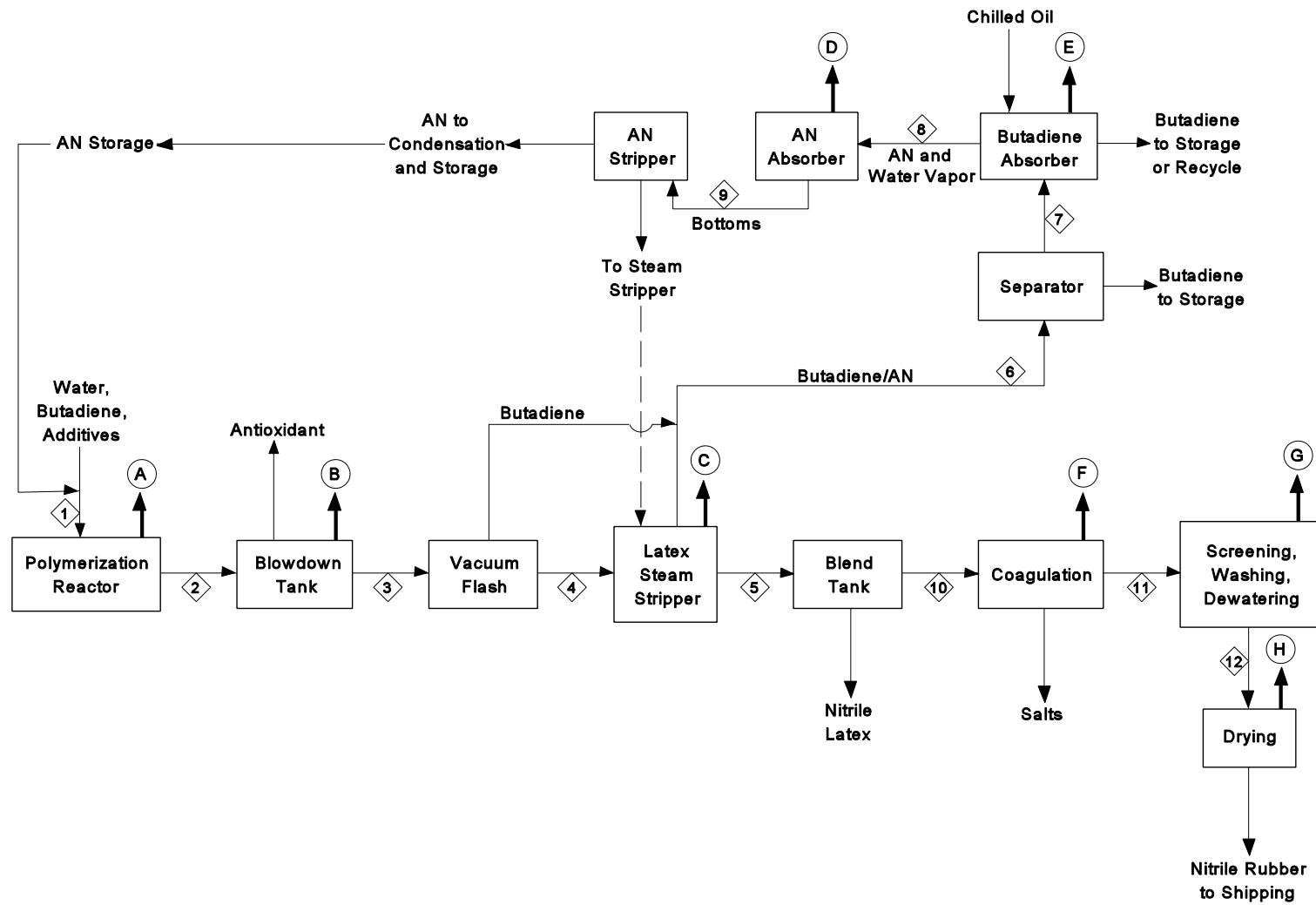
Source: Reference 29.

"--" means capacity not known.

(cumene hydroperoxide as an oxidizing component), sodium formaldehyde sulfoxylate with EDTA (ferrous sulfate complexed with ethylenediamine-tetraacetic acid as the reducing component), and modifiers (alkyl mercaptans).

The reaction is allowed to proceed for 5 to 12 hours. A shortstop solution (sodium bisulfate or potassium dimethyl dithiocarbonate) is added to terminate the reaction at a predetermined point, usually after 75 to 90 percent conversion (depending on the desired molecular weight of the product). The reaction latex is then sent to a blowdown tank (Step 2), where antioxidants are normally added.

The latex is subjected to several vacuum flash steps (3), where most of the unreacted butadiene is released. It is then steam-stripped under vacuum (Step 4) to remove the remaining butadiene and most of the unreacted acrylonitrile. The unreacted monomers are sent to recovery and recycling. Stripped latex at about 110 to 130°F (43 to 54°C) is pumped to blend tanks (Step 5).



Source: Reference 41

Figure 5-9. Process Diagram for Production of Nitrile Elastomer

Gases released in the flash steps and stripped overhead contain butadiene. These gases are sent to a partial condenser (not shown) and separator (Step 6), where butadiene vapor is condensed and sent to liquid storage. Uncondensed butadiene vapor from the separator flows to an absorber (Step 7), where it is absorbed by countercurrent contact with chilled oil. The absorber bottoms are pumped to a flash tank (not shown), and dissolved butadiene is released and returned to the compressor. The hot lean oil is then cooled, chilled, and returned to the top of the absorber.

Unreacted acrylonitrile in flash vapors and latex stripper overhead is recovered by sending these gases to a water absorber (Step 8). Absorber bottoms and the liquid phase of the latex stripper overhead are pumped to a steam stripper (Step 9). The overhead vapor stream from this stripper is condensed in a decanter. Phase separation is allowed to take place and the acrylonitrile phase is decanted to storage. The water-rich phase with residual acrylonitrile is returned to the stripper.

Latex is pumped from the blend tanks (Step 5) to a coagulation tank (Step 10), where the emulsion is broken by the addition of dilute inorganic salt solution (sodium chloride or aluminum sulfate) or a weak organic acid. The slurry of fine polymer crumb is then filtered to remove coagulating chemicals (liquor is recycled) and may be reslurried for further purification. Crumb is dewatered in an extruder (Step 11), then hot-air dried (Step 12). Dried rubber is weighed, pressed into bales, and prepared for shipment.

If latex is the desired end product, the final processing steps (coagulation, screening, washing, and drying) are omitted. The initial steps are essentially identical to those for solid rubber production.⁴⁰

5.6.2 Emissions

The availability of emissions data for nitrile elastomer is somewhat limited. At coproduction facilities, the estimated butadiene emissions include releases from other elastomer production processes. For the two facilities that are also SB copolymer producers, the percent of

the total reported emissions assigned to the NBR process was based on the percent of total production resulting in nitrile elastomer in 1984. Table 5-14 summarizes emissions for process vents, equipment leaks, and secondary sources. All nitrile elastomer production was assumed to be operating at full capacity.⁴⁰ Emissions from emergency and accidental releases and transfer/handling were not known and storage vent emissions from butadiene storage were expected to be low because of the use of tanks under pressure.

Process Vent Emissions

All six facilities for which emissions data were reported use some level of emissions control. Many of the controls that are designed to reduce acrylonitrile emissions are also effective in reducing butadiene emissions (flares, for example). Data from 1984 for four of these facilities are summarized as emission factor ranges in Table 5-14 (see Tables C-21 and C-22 in Appendix C for facility-specific data). The fifth is not used because calculation of an emission factor might reveal confidential business information on production capacity. Potential vent locations, shown in Figure 5-9 as Vents A through H, are based on information on the vent locations supplied by five facilities.

The emission factor ranges were developed as described in Section 4.0. The facility emission factor range includes the various levels of control that each facility has in place. Control efficiencies varied from 89 percent to 99.9 percent. The uncontrolled emission factor range represents potential emissions if controls were not in use.

Equipment Leak Emissions

The estimates for equipment leaks provided by three facilities span three orders of magnitude (Table 5-14). These estimates include the level of control at butadiene producers because of how the average emission rates were derived. The only known control devices currently in use are rupture discs and a flare for pressure relief devices by one facility. The other three facilities indicate daily visual inspection of equipment; however, no repair programs were described for any of the leaks found. Although some controls are in place, detailed information that could be used to compare practices with those at butadiene producers was not available.

TABLE 5-14. SUMMARY OF EMISSION FACTORS FOR NITRILE ELASTOMER PRODUCTION FACILITIES^{a,b}
(FACTOR QUALITY RATING E)

Emission Sources	Facility Emission Factors		Uncontrolled Emission Factors	
	Range ^c	Mean	Range	Mean
Process Vents	0.0004 - 17.80 lb/ton (n=6)	~ 4 lb/ton	0.030 - <50 lb/ton ^d (n=6)	~ 16 lb/ton
3-01-026	(0.0001 - 8.90 kg/Mg)	(~ 2 kg/Mg)	(0.01 - <25 kg/Mg)	(~ 8 kg/Mg)
Secondary Sources ^e	0.002 - 0.018 lb/ton (n=2)	0.010 lb/ton	0.002 - 0.018 lb/ton (n=2)	0.010 lb/ton
3-01-026	(0.001 - 0.009 kg/Mg)	(0.005 kg/Mg)	(0.001 - 0.009 kg/Mg)	(0.005 kg/Mg)

Source: Reference 40.

Note: Annual emissions from uncontrolled equipment leaks range 0.43 - 18.67 tons/yr (0.39 - 16.93 Mg/yr) and average 8.74 tons/yr (7.93 Mg/yr) (n=3).^a

^a Assumes production capacity of 100 percent.

^b Factors are expressed as lb (kg) butadiene emitted per ton (Mg) produced. Only incomplete data on emissions were available, therefore, values underestimate emissions.

^c Ranges are based on actual emissions reported by the facilities. Thus, values include controls whenever they have been implemented.

^d Upper value used to prevent disclosing confidential operating capacity.

^e Lower end of range is for one solid waste stream; upper end includes solid waste, wastewater and contaminated cooling water.

n = number of facilities.

NA = not available.

Secondary Emissions

One emissions estimate of 132 lb/yr (60 kg/yr) was provided from secondary sources.⁴⁰ This estimate includes wastewater, solid waste, and contaminated cooling water. A second facility also indicated wastewater and solid waste as potential secondary sources.⁴⁰ The butadiene content in the wastewater was undetermined; therefore, emissions could not be estimated. However, the solid waste stream contains 4 ppm butadiene. Based on a generation rate of 1063 lb/day (483 kg/day) and assumptions of continuous operation and total volatilization, the source's emissions potential is approximately 0.02 tons/yr (20 kg/yr).⁴³